Cuk converter

Thursday, March 11, 2021 9:17 AM

Motivation

→ Synthesize a DC-DC circuit that can increase / dec. i/p voltage.

→ Both i/p & o/p currents non-pulsating or continuous.

Buck / Boost / Buck-boost

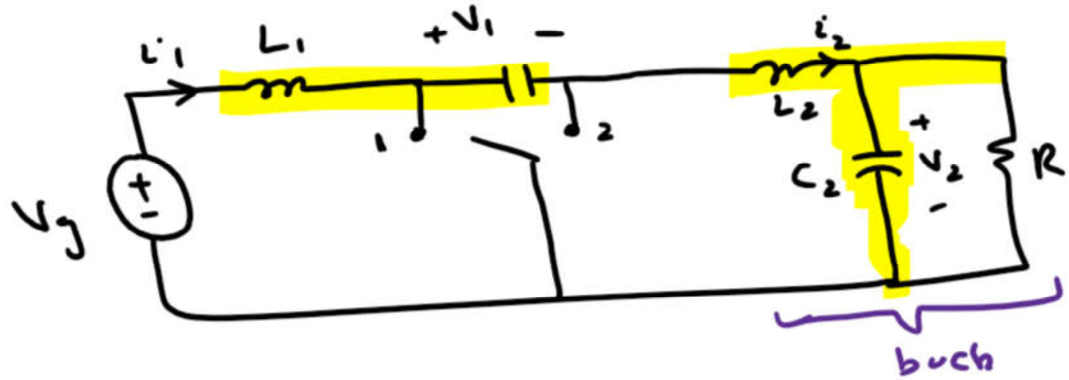
Gain of buck-boost = gain of buck × gain of boost

$$\frac{D}{D'} = \underbrace{(D)\left(\frac{1}{D'}\right)}_{\text{cascaded design}}$$

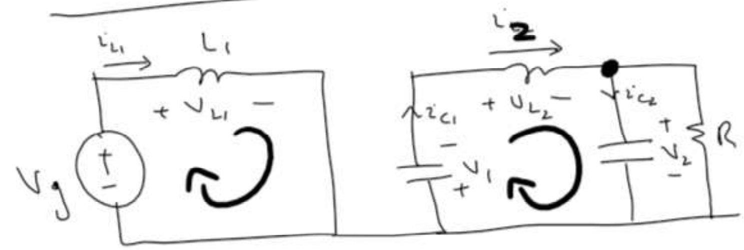
CÚK converter

↳ i/p stage = Boost

↳ o/p " = Buck



At position #1



$V_{L_1} = V_g$ KVL

$V_{L_2} = -V_1 - V_2$ KVL

$i_{C_1} = i_2$ KCL

→ $i_{C_2} = i_2 - \frac{V_2}{R}$ KCL

small ripple approximation

$V_{L_1} = V_g$

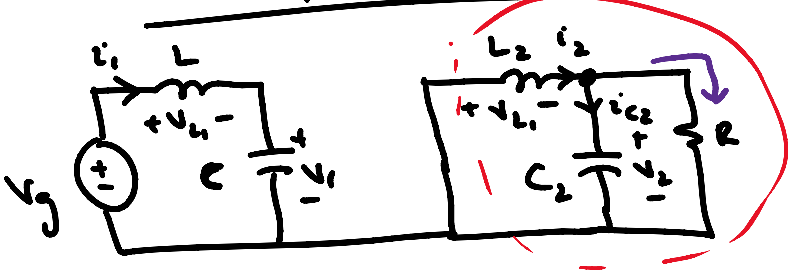
$\boxed{V_{L_2} = -V_1 - V_2}$

$$\boxed{v_{L2} = -V_1 - V_2}$$

$$i_{c_1} = I_2$$

$$i_{c_2} = I_2 - \frac{V_2}{R}$$

At position #2



$$\left.\begin{aligned} v_{L1} &= V_g - V_1 \\ v_{L2} &= -v_2 \end{aligned}\right\} \text{KVL}$$

$$\left.\begin{aligned} i_{c_1} &= i_1 \\ &\boxed{i_{c_2} = i_2 - \frac{V_2}{R}} \end{aligned}\right\} \text{KCL}$$

Small ripple approximation

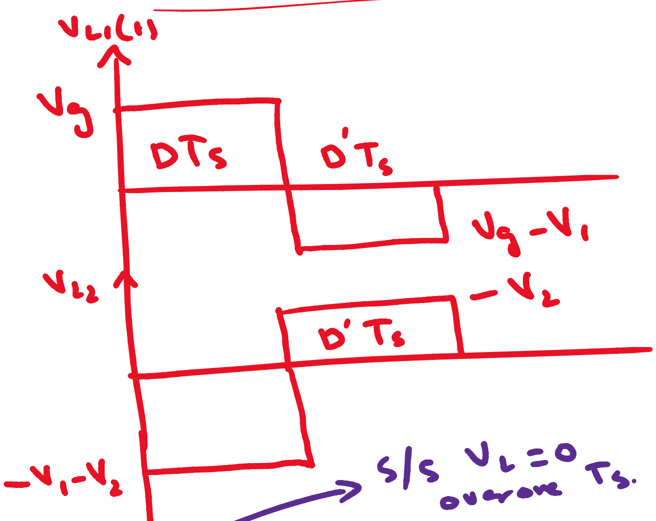
$$v_{L1} = V_g - V_1$$

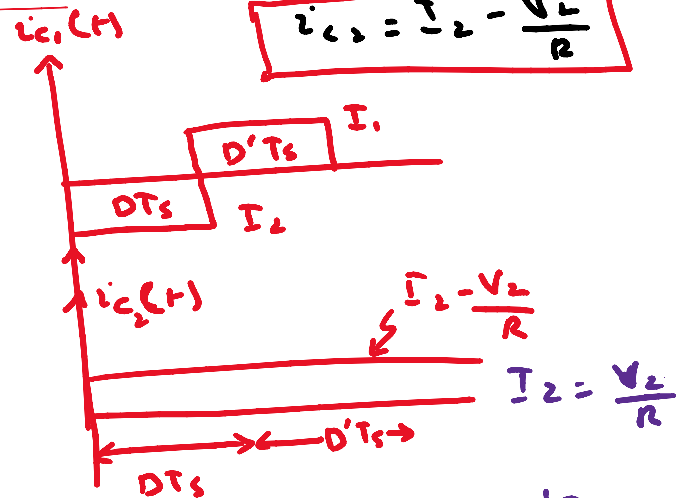
$$v_{L2} = -V_2$$

$$i_{c_1} = I_1$$

$$\boxed{i_{c_2} = I_2 - \frac{V_2}{R}}$$

Drawing the key waveforms





s/s $v_L = 0$ over one T_s.

$$\langle v_{L1}\rangle = 0 = V_g D + D'(V_g - V_1)$$

$$= V_g / D'$$

$$\langle v_{L2}\rangle = 0 = D(-V_1 - V_2) + D'(-V_2)$$

$$V_2 = -\frac{D}{D'} V_g \quad \text{— (A)}$$

$$\langle i_{c_1}\rangle = 0 = D I_2 + D' I_1$$

$$I_1 = \left(-\frac{D}{D'}\right) I_2 = -\frac{D}{D'}\frac{V_2}{R}$$

using (A)

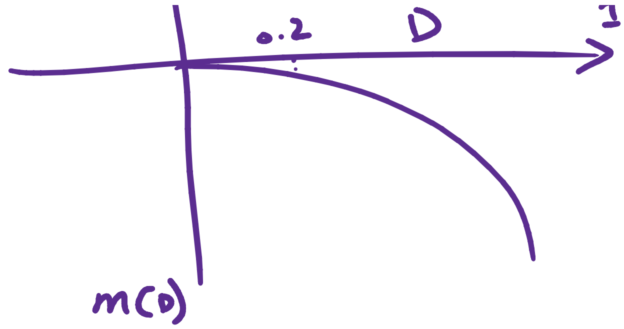
$$= \left(\frac{D}{D'}\right)^2 \frac{V_g}{R}$$

$$\langle i_{c_2}\rangle = I_2 - \frac{V_2}{R} = 0$$

$$I_2 = -\frac{D}{D'}\frac{V_g}{R}$$

$$M(D) = \frac{V_2}{V_g} = \frac{-D}{D'} = \frac{-D}{1-D}$$

V_g D

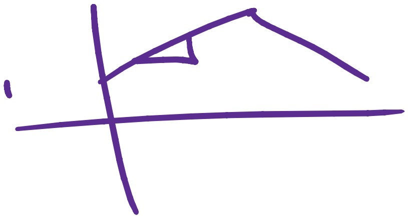


for $D > 0.5$ $\quad V_2 > V_g$

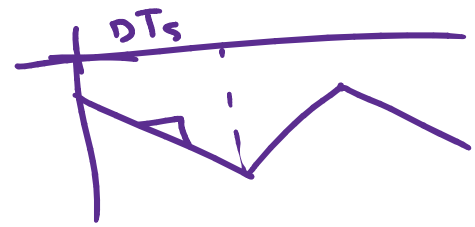
$D < 0.5$ $\quad V_2 < V_g$

$D = 0.5$ $\quad V_2 = V_g$

L_1 Expression based on i_{L_1}

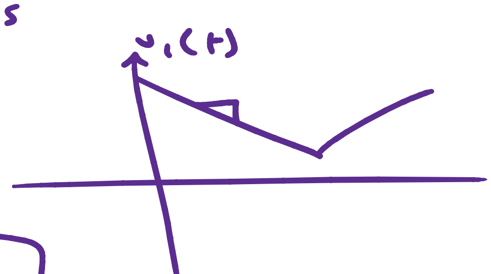


$$\boxed{= \frac{V_g}{2\,\Delta i_1} DT_s}$$



L_2 expression

$$L_2 = \frac{V_1 + V_2}{2\,\Delta i_2} DT_s$$

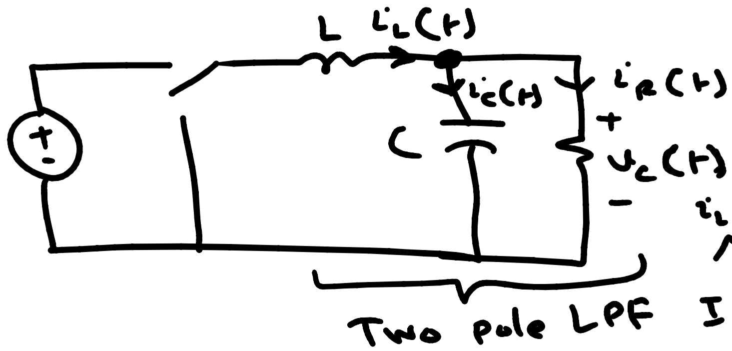


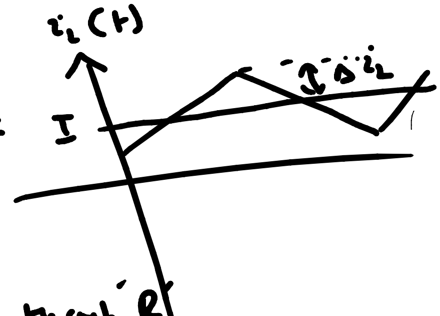
C_1 expression

$$\boxed{= \frac{I_2}{2\,\Delta v_1} DT_s}$$

how to determine the C_2.

→ $i_{c_2}(t)$ is continous.





$$i_2(t) = I + \Delta i_2$$

— ... flow trough R

$i_L(t) = I$

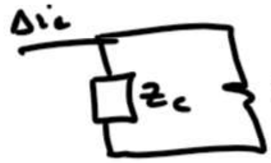
DC component I can only flow through R

I can't flow through C.

b/c $X_C = \frac{1}{2\pi f c} = \infty$ so I can't flow through C.

$\Delta i_L \rightarrow R$

$\Delta i_L \rightarrow C$



If $Z_c > R$

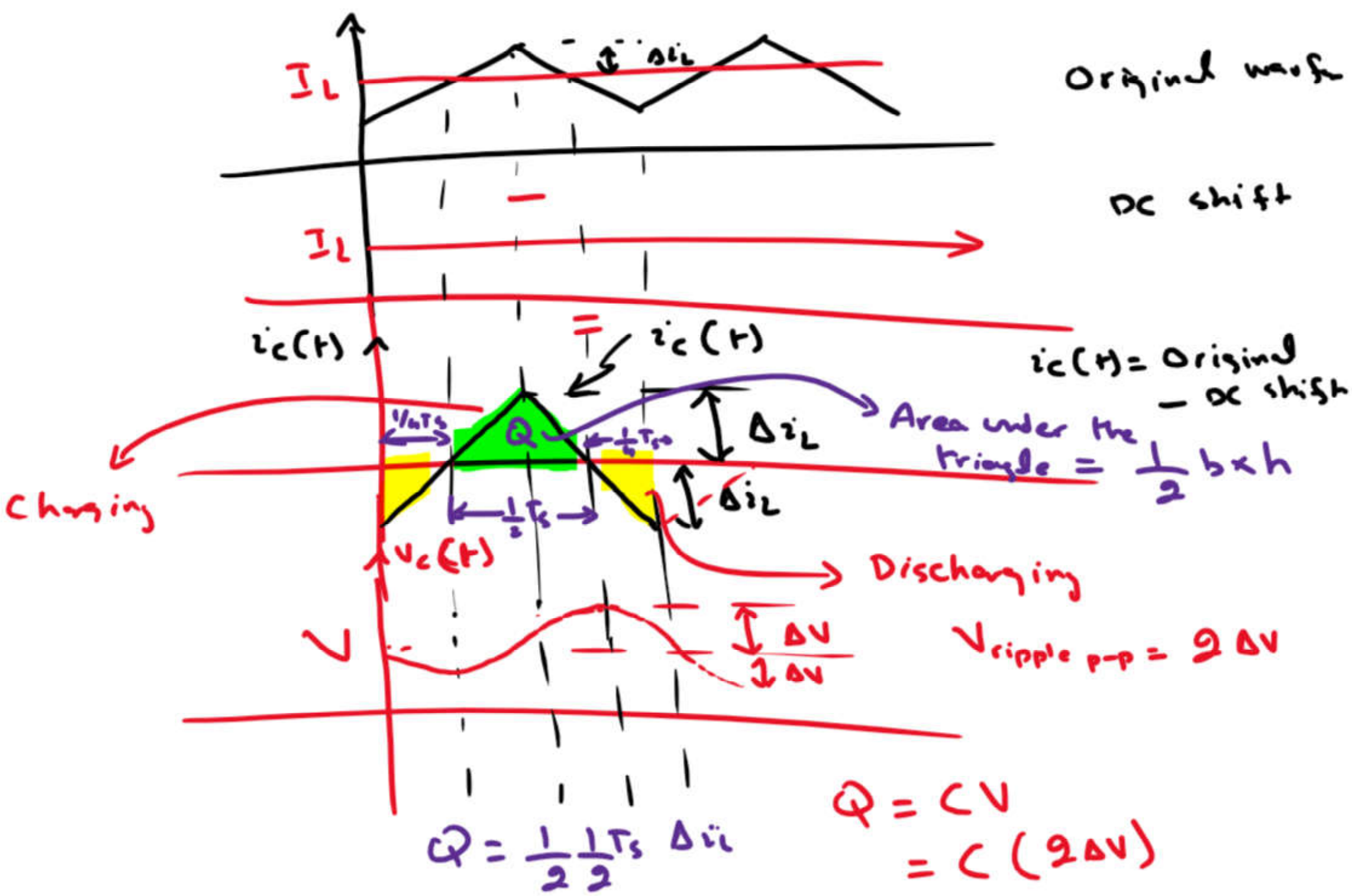
$Z_c < R$

In a well designed converter

$$X_C << R$$

To ensure this C is kept large $X_C = \frac{1}{2\pi f C}$

Ideally all Δi_L flows through 'C'



$Q = CV$

$= C(2\Delta V)$

$Q = \frac{1}{2}\frac{1}{2}T_s \Delta i_L$

$= \frac{\Delta i_L}{4 f_s}$

$C = \Delta i_L$

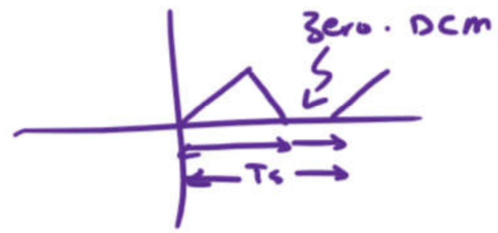
$$\boxed{C = \frac{\Delta i_L}{8 f_s \Delta V}}$$

Discussion

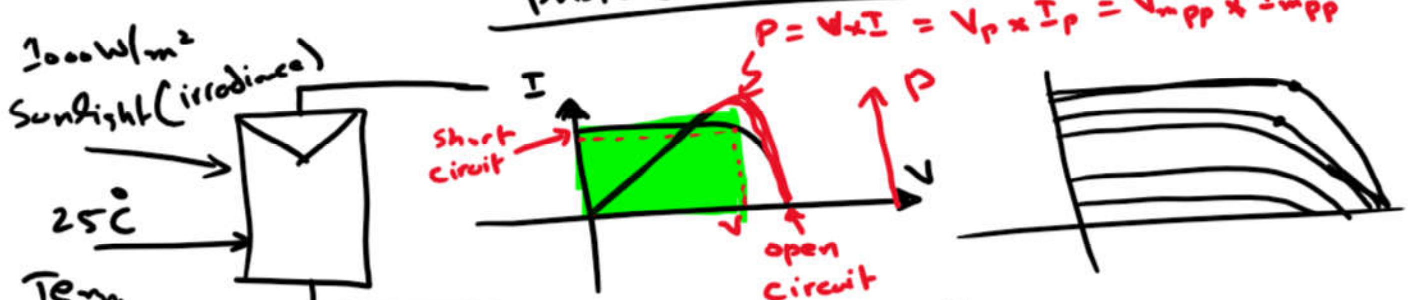
1) All DC-DC are non-linear.

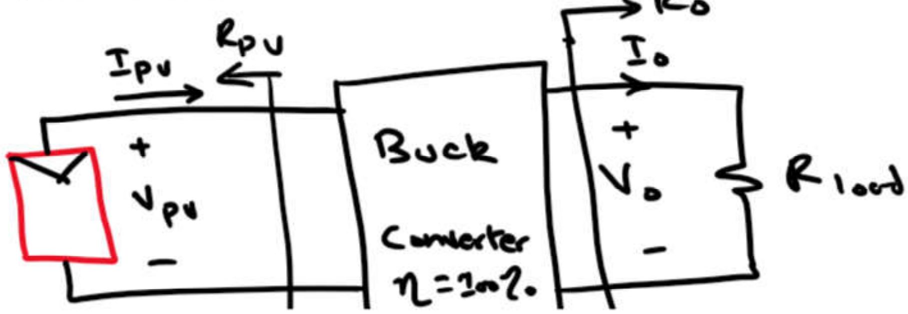
↳ subcircuits are linear [first order / 2nd order]
but high freq switching changes their structure & its periodic structured change make the converter itself a non-linear circuit.

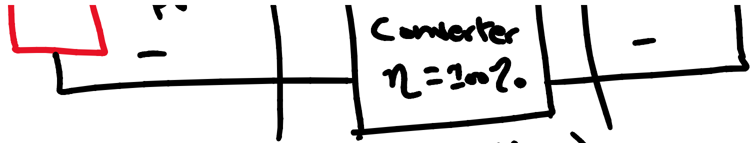
→ In All converters, $i_L > 0$ so this is called continuous conduction mode (CCM).



Application of basic converter in photovoltaic system.





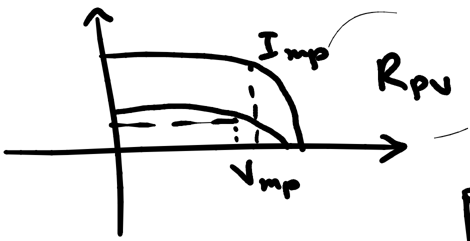


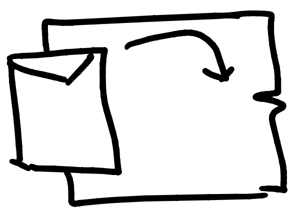
$V_o = D V_{in}$

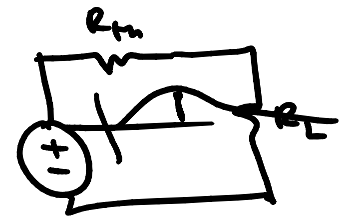
$V_o = D V_{pv}$

$P_{in} = P_o$ $\quad$ $I_o = I_{pv}/D$

$$R_{pv} = \frac{V_{pv}}{I_{pv}} = \frac{V_o/D}{I_o D} = \frac{V_o}{I_o D^2} = \frac{R_o}{D^2} = \frac{R_{Load}}{D^2}$$





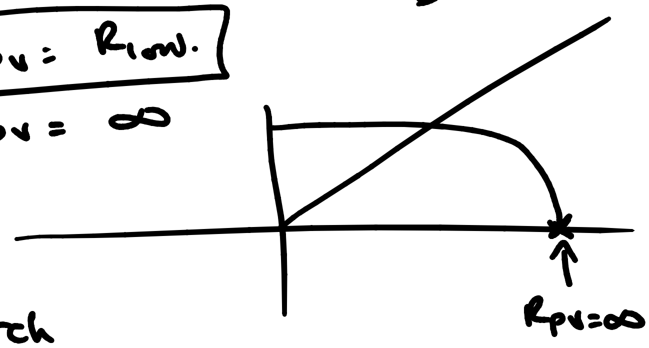


$R = R_{pv}$

$$R_{pv} = \frac{R_{Load}}{D^2}$$

If $D = 1$ $\quad \boxed{R_{pv} = R_{load}.}$

$D = 0$ $\quad R_{pv} = \infty$



If $R_{load} > R_{pv}$

buck converter can't match the impedance & hence can't transfer the MPP or it can't track MPPT.